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DEVELOPMENT OF NEUTRON SHIELDING MATERIAL FOR CASK

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Introduction

Since 1980's Mitsubishi Heavy Industries, Ltd. (MHI) has established transport and storage cask design "MSF series" which realizes higher payload and reliability for long term storage.

MSF series transport and storage cask uses new-developed neutron shielding material. This neutron shielding material has been developed for improving durability under high temperature condition for long term.

This paper summarizes an outline of this new-developed epoxy resin base neutron shielding material.

Purpose of development

- Outline of neutron shielding material

Overall external view of the MSF series transport and storage cask is illustrated in Figure 1. Neutron shielding material is installed in the concentric space between the body and the outer shell and has the function of absorbing neutrons generated by spent fuel. Neutron shielding material should be satisfied with high content of hydrogen, self-fire-extinction property, durability for long-time use, and so on.

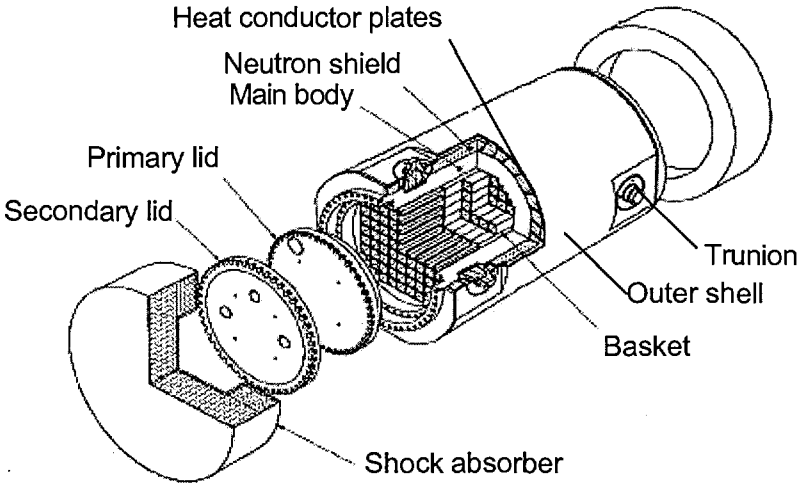

Fig.1 Cask external shape

- Purpose of development

Since epoxy resin contains a lot of hydrogen and is comparatively resistant to heat, many casks employ epoxy base neutron shielding material. However, if the epoxy base neutron shielding material is used under high temperature condition for a long time, the material deteriorates and the moisture contained in it is released. The loss of moisture is in the range of several percents under more than 150 C.

For this reason, our purpose was to develop a high durability epoxy base neutron shielding material which has the same self-fire-extinction property, high hydrogen content and so on as conventional.

Outline of new-developed neutron shielding material

It has been clear that the durability of shielding material depends on purity of refractory material. The refractory material of which main ingredient is aluminum hydroxide provides shielding material with self-fire-extinction property. As a result of our investigation, it has been confirmed that its degradation is caused by sodium compounds which aluminum hydroxide contains as an impurity. The sodium compounds decompose and release moisture at about 150 C or less.

Therefore the new-developed neutron shielding material has been added with refractory material of which impurity is 0.1wt% or less. It has been predicted that its moisture loss is 1% or less even at 170 C for 60 years.

Besides, the new-developed neutron shielding material has also self-fire-extinction property and its extent of damage after fire accident is small. As the result of demonstration test, flame on the material has been eliminated and approximately 78% of neutron shielding material have remained after the fire resistance test at 800 C for 30 minutes.

Specifications of the developed neutron shielding material are shown in Table 1.

Type	Item	Specifications
Composition of neutron shielding material	Main agent	Epoxy resin
	Refractory material	Aluminum hydroxide
	Neutron absorbing material	B_4C
Properties of neutron shielding material	Density(g/cm^3)	1.67 ± 0.05
	Hydrogen content (g/cm^3)	0.096 or more
	B_4C content (g/cm^3)	0.194 or more

Table 1 Specifications of neutron shielding material

Demonstration test

In order to confirm the application of the new-developed neutron shielding material to be used in casks, the following tests were done.

Long-time heating test

In order to check the degradation (moisture loss) of the neutron shielding material, a long-time heating test was done.

- Test method

Since the neutron shielding material is used in a close containment in the casks, test piece of neutron shielding material was also contained in a stainless case. The gas in the case was replaced with an oxygen-nitrogen mixture gas. The specimen was placed in a constant-temperature bath.

- Test results

According to the long-time heating test, the weight loss of the neutron shielding material after 5000 hours heating is shown in Fig. 2. The weight loss after 5000 hours has been lower than approximately 0.04% at 150 C and approximately 0.35% at 170 C respectively. The result of these tests shows that the reliability of the high durability neutron shielding material under high-temperature condition has been improved by increasing purity of refractory material and that it can be employed in casks.

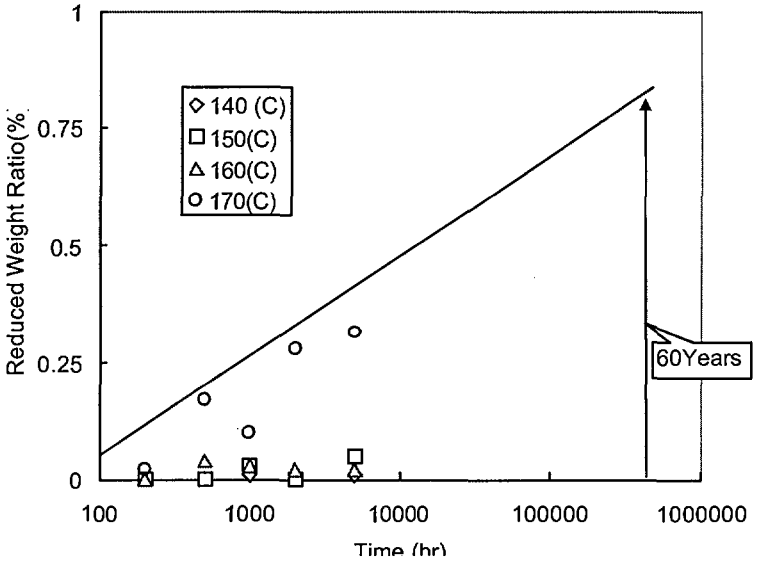

Fig. 1 Results of long-time heating test

Thermal test

Extent of damage and self-fire-extinction property which are fundamental requirements for cask use were confirmed by fire test.

- Test method

Test specimen

The specimen of neutron shielding material is comprised of test piece and insulator covered with stainless steel case as shown in Fig. 2.

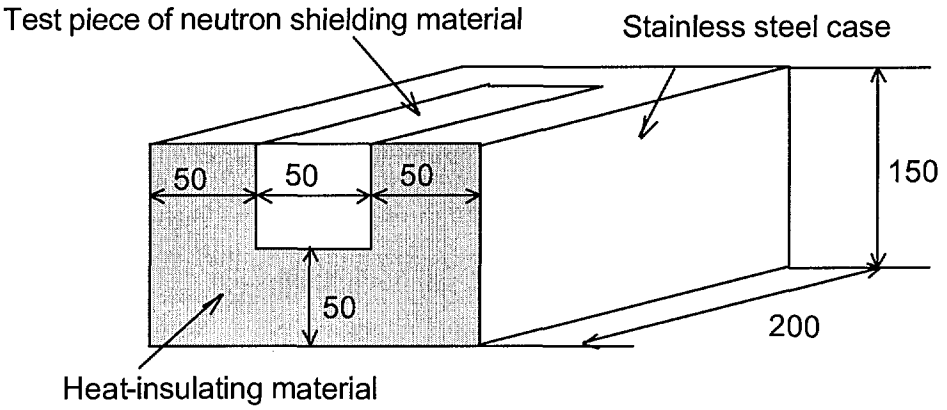

Fig. 2 Test specimen (Units: mm)

Test method

The specimen was inserted in furnace under condition of 800 C of ambient temperature for 30 minutes, and was taken out of the furnace, then was left to cool down in the atmosphere.

- Test results

The external view of the test piece upon completion of the fire test is shown in Fig. 3. The cross-section of the center part of the test piece is shown in Fig. 4. These views show that only a thin layer of the test piece was carbonized.

Fig. 3 Photograph of test piece after fire test

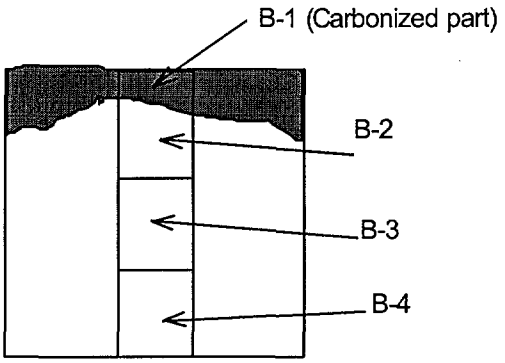

Fig. 4 Cross-section of test piece after fire test

Comparison of weight, density, and components weight of the neutron shielding material between before and after the test are shown in Tables 3, 4, and 5, respectively. According to the test, the weight of test piece has been reduced approximately by 22%, and except the carbonized region of the surface layer, its loss of density has been limited only to a few percents.

Test piece	Weight before test (g)	Weight after test (g)	losing weight ratio (wt %)	Notes
A	619.7	485.6	21.6	with thermocouple
B	620.4	487.8	21.4	

Table 3 Comparison of test piece weight before and after fire test

	Measurement (g/cm^3)			Mean	Loss
Test piece before test	1.67	1.67	1.66	1.67	
B-1	Measurement impossible			-	-
B-2	1.64	1.60	1.63	1.62	-0.05
B-3	1.64	1.63	1.64	1.64	-0.03
B-4	1.62	1.63	1.62	1.62	-0.05

Table 4 Comparison of density before and after fire test

	Measurement (wt%)			Change (wt%)		
	H	C	N	H	C	N
Test piece before test	5.85	27.6	1.14			
B-1	1.48	15.0	0.30	-4.37	-12.6	-0.83
B-2	5.43	26.9	1.34	-0.42	- 0.7	0.20
B-3	5.61	27.3	1.30	-0.24	- 0.3	0.16
B-4	5.54	27.2	1.30	-0.31	- 0.4	0.16

Table 5 Comparison of component weight before and after fire test

Conclusion

Conventional neutron shielding material is degraded in high temperature condition. It has been made clear that this degradation is caused by refractory material impurity. Accordingly, a high durability neutron shielding material with improved refractory material has been developed. This material has been confirmed to present reduced degradation in high temperature condition as well as fire-resist-property.

The new-developed shielding material is used in the MSF series casks.